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Hormonal regulation of flowering and fruit development: Effect of gibberellic acid and ethrel on fruit setting and development of *Momordica charantia* L.

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Abstract

Fruit setting and development in a monoecious cucurbit, *Momordica charantia* L. could be regulated by the external application of gibberellin (GA_3) and ethrel. Both GA_3 and ethrel in lower concentrations promoted female flower production as well as fruit setting and development. Both growth regulators improved the quality of the *Momordica* fruit by increasing length, breath and biomass of the fruits as well as by increasing the content of total sugar of the fruit.

Introduction

Fruit setting and development are two developmental processes at the reproductive phase of a plant which are controlled by internal hormonal balance. Consequently both fruit setting and development could be regulated by external application of plant growth substances similar as flowering and sex expression. Gibberellin (GA_3) regulated fruit development in some non-cucurbits was reported earlier. GA_3-induced fruit setting was shown in lingoberries (Holloway-Patrica *et al.* 1982) and *Citrus sinensis* (Augusti *et al.* 1982), GA_3-regulated fruit setting in the legume *Pisum sativum* (Garcia-Martinez and Carbonell 1985). The role of endogenous GA_3 in seed and fruit development was reported also in tomato (Groot-Steven *et al.* 1987).

Reports on the effect of ethrel on fruit development in cucurbits or other plants are scanty. Fruit setting is strongly related to female flower formation. Formation of female flowers, *i.e.*, sex expression, could be regulated by external application of gibberellins and ethrel. GA_3-induced femaleness was reported in *Luffa acutangula* (Bose and Nitsch 1970) and in *Momordica charantia* (Ghosh and Basu 1983). However, Prakash (1977) reported promotion of male bud development in *Momordica* by GA_3. Ethylene was claimed as an endogenous femaleness-inducing factor of cucumber and muskmelon (Byers *et al.* 1972) and an increase in femaleness of three cucurbits by treatment with ethrel was reported by Rudich *et al.* (1969),

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Sadhu and Das (1978) and Hume and Lowell (1983). On the other hand, Saimbhi (1978) found no changes in sex expression with CEPA (ethrel).

GA_3 and ethrel may also regulate yield and quality of the fruits. Ethephon was shown to increase the yield and quality of fruits of *Capsicum annuum* (Choi *et al.* 1987). Kim *et al.* (1988) reported GA_3 increased fruit setting, enlarged size and increased yield in *Cucumis sativus.*

The purpose of this study was to examine the effect of GA_3 and ethrel on fruit setting and development, and on the quality of fruits of *Momordica charantia,* an important fresh vegetable in the Indian Subcontinent. The work done earlier on this cucurbit forwared contradictory results as mentioned earlier.

Materials and methods

Seeds of *Momordica charantia* L. (locally known as "Karala") were collected from Bonpus Nursery, Burdwan. The climber is a monoecious cucurbit, producing male and female flowers on the same plant. The plants were cultivated in an experimental field in natural condition with a Randomized Block Design following Ghosh and Basu (1982). There were three treatments of each concentration of growth regulator, each experiment being replicated 4 times.

The studies on the effect of GA_3 on flowering, fruit setting and development were performed from September to early December with average temperature of 25±5 °C. The experiments with ethrel were conducted from October to early January with an average temperature of 22 ± 5 °C. The observations were extended up to 90 d of age of the plants from germination of the seeds. The number of flowers includes also flower buds. Statistical analyses were carried out at 5% significance level following Panse and Sukhatme (1985).

Solutions of GA_3 or ethrel were sprayed at 3-5 leaf-stage on the foliage with a glass hand sprayer. Distilled water was sprayed on the control plants. At the begining of the flowering phase of the plants, two additional sprays with GA_3 or ethrel were given as booster dose to support the fruit set and development. Total sugar was extracted and estimated according to McCready *et al.* (1950), total chlorophyll content of the fruit was extracted and estimated following Arnon (1949).

Results

Momordica charantia is a monoecious cucurbit which possesses four distinct phases of growth in the life of the plant, *viz.*, vegetative phase, male phase (when only male flowers are developed), mixed phase (when female flowers are also developed in addition to male ones) and abortive female phase (when most of the female flowers are abortive in the later part of the mixed phase). Fruits are produced from the female flowers of the mixed phase.

Both GA_3 and ethrel had much impact on flowering of *M. charantia.* At the concentration of GA_3 of 40 mg l^{-1} and ethrel of 25 mg l^{-1} the number of female flowers was more than doubled, while the increase in the number of male and total

flowers was not so pronounced. The ratio of male to female flowers became the lowest with these concentrations of GA_3 and ethrel. The highest concentrations of GA_3 and ethrel were inhibitory (Table 1).

Table 1. Effect of GA_3 and ethrel on sex-expression and fruit setting of *Momordica charantia.*

Growth regulators	Concentration [mg l^{-1}]	Mean number of flowers total	male	female	Mean number of fruits (total)	Fruit formation [%]	Ratio of male/ female flowers
control	-	75.66	64.33	11.33	6.00	52.96	5.11
GA_3	40.00	102.33	77.33	24.00	19.33	80.54	3.22
GA_3	80.00	92.66	74.66	18.00	13.66	75.92	4.14
GA_3	140.00	48.66	43.66	5.00	3.00	56.28	8.19
CD at 5 % level		6.58	4.80	3.57	1.59	—	—
control							
Ethrel		59.66	49.00	10.66	5.66	53.10	5.28
Ethrel	25.00	79.33	58.00	21.33	15.66	73.41	2.75
Ethrel	50.00	67.00	52.33	14.66	10.00	68.21	3.59
	100.00	49.66	41.33	8.33	5.66	67.94	4.96
CD at 5 % level		4.85	3.09	1.68	1.29	—	—

The percentage of fruit formation was increased in all GA_3- and ethrel-treated plants in comparison with control, even when the number of female flowers was decreased (Table 1). The highest effectivity was observed with 40 mg l^{-1} GA_3, when 80.5 % of the female flowers formed fruits compared with 53 % in the control plants. The most effective ethrel concentration was 25 mg l^{-1}, increasing fruit production to 73.4 %. With ethrel treatment the increase in the fruit formation was by 38.7 % (Table 1).

The size (length and girth) of the mature fruits was increased with both GA_3 and ethrel. At 80 mg l^{-1} GA_3 increased both the lenght and the girth of the mature fruits (Table 2). The increase in length was 70.8 % and in girth 36.6 % over control. After a treatment with 50 mg l^{-1} of ethrel, the increase in length was 33 % and in girth 23.8% (Table 2). In most cases, the length of the mature fruits was increased more than the girth. Also, the rate of increase in both lenght and girth during development of the fruit was higher than in control after the treatment with optimum concentrations of both chemicals (Fig. 1). In both cases the rate of the increase in girth was higher than that in length. The mass of mature fruit was also increased with both treatments (Table 2). The increase was almost 100 % with 80 mg l^{-1} GA_3 and 11.6 % with 50 mg l^{-1} ethrel. We observed another beneficial effect of both treatments on the mature fruit: number of seeds per fruit was decreased (Table 2). Higher concentrations of both regulators were inhibitory to most of these characters.

Table 2. Effect of GA_3 and ethrel on the fruits of *Momordica charantia*.

Growth regulators	Concentration [mg l^{-1}]	Size of mature fruit length [cm]	girth [cm]	Mass of fruit [g]	Number of seeds per fruit
	-				
Control	-	8.12	11.62	42.12	16.0
GA_3	40.00	11.87	13.37	54.50	17.25
GA_3	80.00	13.87	15.87	83.87	13.50
GA_3	140.00	7.87	7.62	24.75	8.00
CD at 5% level		1.42	1.87	2.52	1.79
Control	-	8.00	10.50	41.66	15.66
Ethrel	25.00	8.85	12.20	45.66	10.66
Ethrel	50.00	10.65	13.00	49.00	12.33
Ethrel	100.00	7.18	11.00	27.33	9.66
CD at 5% level		1.00	1.02	2.61	2.06

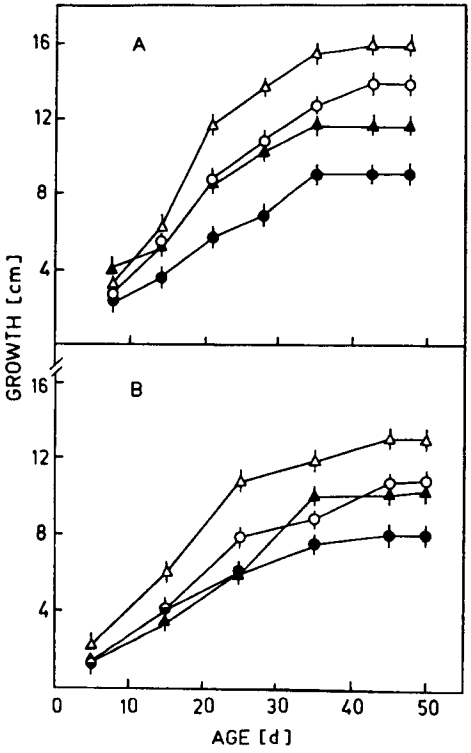

Fig. 1. The rate of increase (*open symbols*) in length (*circle*) and girth (*triangle*) of the developing fruits after GA_3 (80 mg l^{-1}) (A) and ethrel (50 mg l^{-1}) (B) treatment. The control sets have *closed symbols*. Bars represent standard error.

The chlorophyll content of the fruits of the control plants was high in the early stage (5-d old) and sharply decreased with age (Fig. 2). Treatment with GA_3 and ethrel increased the chlorophyll content in the fruits at the early stage, but did not affect the sharp decrease later on (Fig. 2 A, B).

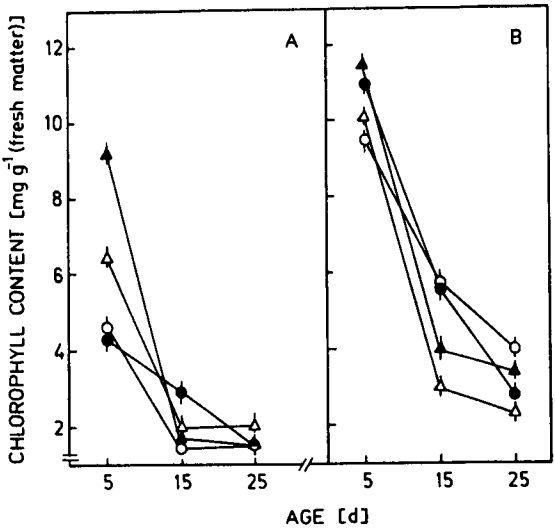

Fig. 2. Effect of GA_3 and ethrel on the chlorophyll content of the developing fruits.
A: Effects of 40 mg l^{-1} (*closed circles*), 80 mg l^{-1} (*open triangles*) and 140 mg l^{-1} (*closed triangles*) of GA_3 are shown. The control has *open circles*.
B: Effects of 25 mg l^{-1} (*closed circles*), 50 mg l^{-1} (*open triangles*) and 100 mg l^{-1} (*closed triangles*) of ethrel are shown. The control has *open circles*.

The total sugar (soluble and insoluble) content of the *Momordica* fruits was increased after both GA_3 and ethrel treatment. After GA_3 treatment, the soluble sugar content was sharply increased in 15-d old fruits, but then was reduced to the control level between the 15th and 25th day (Fig. 3 A). Insoluble sugar content of GA_3-treated fruits was much higher during the whole fruit development; only at the 15th day after 40 mg l^{-1} GA_3 it was as high as in control fruits (Fig.3B).

After ethrel treatment the soluble sugar content was maximum in the 5-d old fruits and the content was reduced with increasing age from 5 d to 25 d (Fig.3C). With 50 mg l^{-1} of ethrel the amount of soluble sugars increased to maximum. After ethrel treatment, the insoluble sugar content was to be the same as in the control fruits in 5-d-old fruits and was higher in 15-d old ones (Fig.3D).

Discussion

Comparatively little information has been available till now about the effect of GA_3 or ethrel on cucurbits other than cucumber and muskmelon. From the presented

results it is evident that both GA_3 and ethrel had feminizing effect on *Momordica charantia* increasing the production of female flowers along with the increase in the

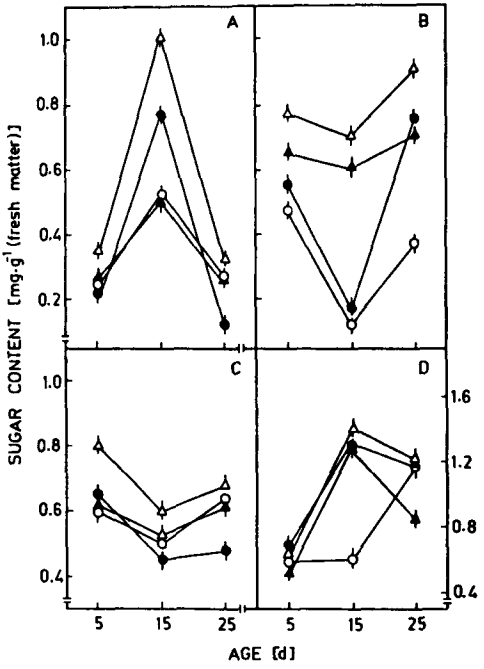

Fig. 3. Effect of GA_3 and ethrel on the content of soluble and insoluble sugars of the developing fruits. Effects of 40 mg l^{-1} (*closed circles*), 80 mg l^{-1} (*open triangles*) and 140 mg l^{-1} (*closed triangles*) of GA_3 are shown on the soluble (A) and insoluble (B) sugar content of the fruits. Effects of 25 mg l^{-1} (*closed circles*), 50 mg l^{-1} (*open triangles*) and 100 mg l^{-1} (*closed triangles*) of ethrel are shown on the soluble (C) and insoluble (D) sugar content of the fruits. In all the figures the control has *open circles*. Bars represent standard error.

total number of flowers. But the ratio of male to female flowers decreased showing an increase in femaleness. Suppression of maleness was more pronounced with ethrel where female flowers were doubled but lower formation of male flowers decreased the total number of flowers. GA_3-induced feminity was already reported in *Luffa acutangula* (Bose and Nitsch 1970) and another variety of *Momordica charantia* (Ghosh and Basu 1982). The level of endogenous GA_3-like substances was increased in the shoot tips at the time when female flower production was much enhancend (Ghosh and Basu 1982). Ethylene has also been shown earlier as a regulator of sex expression, which increased femaleness in cucumber and muskmelon (Rudich *et al.* 1969, Byers *et al.* 1972, Sadhu and Das 1978).

Both GA_3 and ethrel had promotive effect also on fruit setting of *M. charantia*. The percentage of fruit production was increased in all treated plants over control. This finding is in agreement with reports on GA_3-induced fruit set in plants other than cucurbits (Agusti *et al.* 1982, Holloway-Patrica *et al.* 1982, Garcia-

Martinez and Carbonell 1985) and on the effect of ethrel on growth, flowering and fruit formation of three cucurbits (Sadhu and Das 1978).

GA_3 and ethrel also promoted fruit development, increasing length, girth and mass of fruits. Ethrel was less effective in comparsion to GA_3. GA_3 was shown to promote fruit development also in tomato (Groot-Steven *et al.* 1987) and cucumber (Ogawa *et al.* 1989). Moreover, the number of seeds per fruit progressively decreased after both GA_3 and ethrel treatment, increasing thus fruit quality. Another improvement of the quality of this vegetable (fruit) was the increase in total sugar content of the fruits. GA_3 being more effective in increasing the level of soluble sugars, while ethrel that of insoluble sugars. Ethrel probably accelerated the conversion of soluble sugars into insoluble ones, especially with the increasing age of the fruits and GA_3 probably influenced the anabolic reactions in the developing fruits leading to synthesis of sugars.

From the presented results it could be concluded that treatment with both GA_3 and ethrel had beneficial effect not only on fruit setting and development but also on the quality of the fruit.

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